

COMPREHENSIVE SOLUTION FOR LIGHTNING PROTECTION

Malaysia, being close to the equator, has one of the highest records of lightning strikes amongst the countries in the world. Malaysian Meteorological Centre recorded more than 300 days of lightning in a year in certain parts of the country. Loss of human lives, costly equipment and important installations being destroyed or disabled by such incidences are being reported every year causing enormous lost and inconvenience.

Lightning discharges can occur between or within clouds, or from cloud to ground. Only cloud to ground flashes effects us most. The direct and indirect effect of these discharges and the challenge of protecting against them have become a major focus of attention. Recent research has shown that the typical lightning strike will reach a mean stroke of 20kA and the highest can reach 300kA in about 1.8 to 18 microseconds. When put into numbers the equation is: $e = L (di/dt)$ which means the peak transient voltage per meter conductor length from any surge event (e) is equal to the inductance of the conductor or electrical path per meter (L) times the change in current (di) divided by the rise time (dt). A very conservative calculation will be to assume $L = 1\mu\text{H} (10^{-6})/\text{m}$, $di = 20\text{kA} (20 \times 10^3)$ and $dt = 8\mu\text{s} (8 \times 10^{-6})$. The result is $e = 2,500\text{V}/\text{m}$. If a low voltage power supply of 240V can cause harm to human, imagine the effects of 2,500V.

(I) Direct Lightning Effects and Protection on Structures

Lightning protection was discovered by Benjamin Franklin nearly 200 years ago. Since then there has been little progress in the related technology and products. A direct lightning strike onto a structure will cause external damages that could lead to possible fire and severe damage of electronic, electrical and even mechanical equipment.

The most popular methods of lightning protection have involved sharp (Franklin) rods, horizontal and vertical conductors (Faraday Cage). Experience with these methods has evolved into the “Cone of Protection” and the “Rolling Sphere” techniques for design of lightning protection as recommended by IEC 62305 standard. It recommends extensive down conductors of bare copper tapes at every 10 to 15 meters interval to reduce the risk of side-flashing (where lightning flashes to nearby conductors). However since the invention of microelectronics many finds these

techniques to be ineffective as more and more people continue to suffer damages from lightning. Erecting a copper rod at the top of a structure and laying copper tapes along it, will electrify the whole structure rise and will convert the lightning current into surge when a direct lightning discharges. For concrete structures, the lightning current will travel through the steel columns and induce voltage onto cables and printed circuit boards of the equipment hence causing extensive damage to the equipment, communication breakdown and interrupted operation. As for the metal structures i.e. communication towers, chimneys, silos and structures with metal clad roofs, most as the tip of the structure forms the lightning arrestor (due to its height) while the earthed metal structure becomes the down conductors and earth system. If copper tape and copper rods are added to the structure, the lightning current will still travel through the metal structure and metal clad roofs rather than the copper tape because the conduction area is much larger than that of the copper tape. Therefore the conventional lightning protection for metal structure is inept. As for the sky scrapers, down conductors are often concealed due to aesthetic reasons. By doing this, it voids the lightning protection system as the “Faraday Cage” no longer exists.

Another type of lightning protection called the Early Streamer Emission (ESE) terminal was developed a few decades ago and it is recognized by the French Standard (NFC 17-102). In 1979, A.J. Erikson introduced Collection Volume design in calculating the lightning protection area. This method explains why and when the external of a structure could still be struck by lightning even though a lightning arrestor has been installed especially when the lightning peak current is 3.5kA or less. The concept of ESE terminals is to launch an up-streamer much earlier than all objects above ground to intercept with the down-leader to form the lightning conduction channel. Thereby providing a relatively larger protection radius and is also able to protect open areas such as golf courses, fields, etc. The ESE terminals are also known as the offensive/active lightning protection because it attracts all lightning within its protection radius to hit its terminal. However many manufacturers recommend the use of ESE terminals with one (1) or two (2) down conductors of bare copper tapes only (which can save a substantial cost). The effect is even more disastrous as it dramatically increases the risk of side-flashing and electrification of structure. By attracting lightning to hit its terminal but not being able discharge it safely to ground will cause severe equipment damage within the structure.

An advanced lightning protection system was invented in the 1970's to cater for today's advanced technology in microelectronics. It uses Early Streamer Emission (ESE) technology air terminal,

an electrically sealed lightning carrier and a separate lightning earth with a minimum of 5 meters distance from other earth and structures. The E.F. Carrier System of Lightning Protection is the only worldwide patented Total Lightning Protection System that is able to electrically seal and suppress the primary over-voltage away from the structure but before the earth system. The E.F. ESE air terminal is made of non-radioactive material and powered by the strong electric field present during a lightning storm. The E.F. Lightning Carrier is a coaxial structured cable that performs the task of conveying the lightning current safely to ground without the electrification of structure. It comprises of a rubber center core, a 35 mm² inner copper conductor, an insulator, another 35 mm² outer copper conductor and a protective jacket. All conductor wires of the cable are arranged parallel to the center axis to further reduce their self-inductance. The voltage breakdown of the cable is nearly impossible as the capacitance of the cable stores the lightning energy temporarily and releases the same after the current peak value, in a steadier and smoother manner. This E.F. cable forms a low pass circuit and cannot be compared or substituted with any conventional communication coaxial cable. The termination of the whole system plays an important role in eliminating side-flashing. At the upper end of the cable the outer conductor is left floating while at the lower end the inner and outer conductor is connected to earth. Hence the outer conductor is always at the same ground potential as the nearby objects. This design screens out the electric field produced by the inner conductor and simply means that side-flashing is eliminated.

(II) Indirect Lightning Effects and Protection on Power Systems

Lightning ground flashes can affect low-voltage AC power systems in two ways, namely:

- *Direct Strike:* Lightning discharges to the power system directly, injecting large impulse currents
- *Indirect Strike:* Lightning discharges to the ground nearby, inducing moderate currents and voltages on the power line.

Direct lightning discharges are the most severe events, particularly if they occur to an overhead power line close to the facility service entrance. In these events, the overhead power line voltage will be raised to many hundreds or thousands of volts, almost always causing flashover of insulation. Lightning current will flow in the power line over distances of a mile or more, with peak currents near discharge being up to 100 kA or more. Current on the low-voltage power line

at the service entrance could reach between 5kA to 10kA on each phase conductor. Severe lightning currents from direct discharge events may be expected a few times per year at any given facility in areas exposed to high lightning incidence. These events will occur very infrequently at facilities served from underground power cables or in areas of low lightning incidence.

When AC circuits employs two lines and a separate protection earth, common and differential mode transient can occur. Common mode transient appears as a transient between each line and the earth while differential mode transient appears as a difference between two lines that is independent of their potential differences. Therefore Surge Protective Device (SPD) must provide protection from line to earth (L-G), line to neutral (L-N) and neutral to earth (N-G).

Protective devices used for AC circuits are usually either voltage switching type or voltage limiting type or a combination type. The voltage switching type or sometimes called “crowbar type” uses components such as spark gaps, gas tubes, thyristors (silicon-controlled rectifiers) and triacs. Gas discharge devices are generally not suited to the protection of mains supplies AC circuits because of the fold back nature of their operation (net follow current) and a slower response time. The voltage limiting type or sometimes called “clamping type” uses components such as Metal Oxide Varistors (MOVs) and suppressor diodes. MOVs are normally used because the resistance of varistors drops significantly when the voltage exceeds a limit thus clamping the voltage near the limit.

Because the performance of MOVs degrades with repeated operation, the selection of the surge capacity of the SPD should be in accordance to the panel’s current consumption and redundancy is recommended at lightning prone areas as well as at service entrance. It is crucial for SPD to be equipped with thermal protection for each phase to avoid thermal runaway due to the MOVs degradation. Housing the MOV in metal enclosure will further provide thermal stability and prevent fire hazards. Features such as LED, audible alarm and volt-free contact for connections to remote monitoring will be an added advantage for the monitoring of the SPD protection status.

A multistage parallel protection method is also recommended to provide attenuation of any residual transient energy that gets past the service entrance lightning suppressors especially when the distance between the SPD and the equipment is more than 10 meters. This arrangement will achieve the same performance as the series type SPD without power interruption at a lower cost. A multistage parallel protection will mean incorporating SPD at service entrance (Main

Switchboard) as First Stage Protection followed by Sub-Switchboard as Second Stage Protection and finally at Distribution Board for Third Stage Protection.

Care must be taken to install the SPD before any Earth Leakage Circuit Breakers (ELCB) to avoid nuisance tripping. For optimal performance all connecting leads should always be as short and as straight as possible. SPD should also be added when the facilities and equipment are new and not after suffering repeated damages as this would have already caused significant deterioration to the cabling and equipment.

(III) Lightning Effects and Protection on Data/Communication Lines

However, even with reliable AC surge suppressor in place, many still find themselves plagued by the failures that had previously been relegated to the confines of “power line problems”. Microelectronic equipment that is coupled directly or indirectly onto data/signal/telephone line is extremely vulnerable to transient over-voltages. Prior to today’s extensive local and wide area networks, it was sufficient to provide protection at the AC power source. However current requirements to interconnect computers, telephones and other equipment with multiple voice/data communication links have created many new avenues for transients to travel. The higher data rates allowed by modern LANs require the use of more sensitive transceiver circuits which can be severely damaged by as little as 17 volts. Less than 15 volts can scramble information, disrupting the on-line reliability.

Many communication lines networked between buildings are run through gas tube protectors. These protectors typically response to voltage rises in a matter of several microseconds, but the delicate semiconductor junctions of modern electronic circuitry require a response time of less than 10 nanoseconds to prevent voltage rise to unsafe levels.

Protective devices used for data line SPD are generally solid state devices. These devices consist of special zener diodes which exhibit voltage limiting characteristics with breakdown voltages in the range of 5V to 200V. The current ratings are up to several hundred amperes but the response time is in 10 picoseconds. The suppression technology used is normally designed to handle fast, low energy level transients generated by differential ground potential between peripherals, and

noise sources within a building's localized environment, not the energy levels associated with lightning and other external disturbances.

Since the data line SPD is the last line of defense, it must be installed in series and adjacent to the equipment. Key considerations for choosing the correct data line surge suppressors are the system application, the type of interface connection, and the baud rate of the system. To provide adequate protection for communication line a point-to-point protection is required. Protection must be provided on both ends of a cable interconnect at each piece of equipment intending to be protected.

In conclusion, a lightning protection for today's environment must include all three types of lightning protection (direct lightning protection for structures, SPD for power systems and SPD for data/communication lines). A poor choice of protection is sometimes much worse than no protection. Last but not least a very good earth system and arrangement for all the above mentioned is also very crucial.

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